ASSESSING AIRCRAFT SURVIVABILITY TO HIGH FREQUENCY TRANSIENT THREATS

SUMMARY

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ABSTRACT

Throughout the United States Department of Defense (DoD), the need exists to assess and characterize aircraft system survivability to High Frequency (HF) electromagnetic (EM) transient threats. These threats include the HF Electromagnetic Pulse (EMP) and other ultra wideband (UWB) transient environments. The Navy recognizes this need and is taking the initiative to investigate the feasibility of a realistic, low-cost test methodology to assess, characterize and validate aircraft survivability to threats that may range from a few hundred Kilohertz to the low Gigahertz region. The proposed Navy technical approach is based on established system-level RDT&E technology using existing high frequency test laboratories and equipment. The approach will be validated using a combination of High Level Pulse (HLP) testing at the Naval Air Warfare Center Aircraft Division Patuxent River's Horizontally Polarized Dipole (HPD) and Vertically Polarized Dipole (VPD) free-field EMP simulators, electromagnetic effects generating equipment to simulate the carrier shipboard environment, free-field low-level continuous wave (LLCW) testing to acquire the stress response data, and wideband direct-drive tests to characterize system strength. The Navy is developing a new wideband (up to 1 GHz) direct-drive technology and waveform combination techniques using stress response data to develop worst-case stress envelopes to be used during the direct-drive tests. Several technical issues must be addressed including recording test data at the high frequencies (300 MHz-1 GHz), quantification of the actual changes in coupling between previous and new EMP specifications, characterization of the effect that higher frequency EM fields have on weapon system survivability, and definition of the minimum required test capabilities to keep uncertainties within bounds.

Enclosure (2)

INTRODUCTION

A need exists to determine aircraft survivability to HF EMP and other transient environments (UWB). To date, no United States tactical aircraft has been tested to the latest defined threat environment. All existing combat aircraft stress response data has been to Bell Laboratories EMP criteria, therefore the impact on aircraft survivability to transient threats greater than approximatly 150 MHz is unknown. Ideally, full-threat, free-field simulators, generators and emitters would be developed for system-level testing to the defined HF threat and the multitiude of shipboard emitters. However, the costs associated with development and procurement of these facilities and types of equipment can be excessive with the ever-changing threat environments. Therefore, a low-cost alternative to assessment by simulated, full-threat free-field illumination must be found and a realistic test capability for assessing aircraft and other weapons systems to HF threats developed. The technical approach described in this paper is based on using current HLP EMP simulators, EM effects generators and LLCW technology and resources, combined with significant improvements and enhancements to direct-drive current-injection test technology, to develop a low-cost test methodology to assess and validate aircraft survivability to EMP and other HF threats. The primary purpose of this effort is to develop an approach for validation of an abbreviated test methodology for assessing aircraft survivability to HF threat environments. The primary objectives of the assessment approach are to:

1. Assess the effect of the expanded EM threat defined by shipboard environments UWB threats and EMP requirements on aircraft survivability.

2. Develop a realistic, low-cost test methodology needed to assess and validate aircraft survivability;

3. Develop an HF direct-drive current-injection capability (100 MHz-1 GHz);

4. Perform the system-level validation tests required to evaluate LLCW test techniques to bound high frequency stress responses for aircraft;

5. Validate the feasibility of using waveform combination techniques to combine multiple high level pulse, shipboard transients, and LLCW measurements into composite waveforms (stress envelopes) to be used during direct-drive testing;

6. Define the minimum test capabilities needed to assess and validate aircraft survivability, including facilities, simulators, instrumentation, data processing and analysis techniques; and

7. Estimate tradeoffs between test fidelity and cost.

TECHNICAL APPROACH

Traditionally, aircraft EMP survivability assessments have relied on high fidelity stress/strength simulations to allow fast low risk evaluations. Plans to fully upgrade the existing capability to accommodate higher frequency threats have been estimated at up to $20M. Given the present DoD situation, it is unlikely that this plan will be implemented. As a low-cost alternative, the Navy is hoping that development of a HF Direct-Drive system used in conjunction with the existing high level pulse simulators (perhaps with modest improvements) will prove to be adequate.

There are many issues which may make the low-cost alternative an adequate test technology. Some of the more obvious issues include:

1. The ability to bound the stress and build composite waveforms for direct-drive (10 kHz - 1 GHz Bandwidth). This is a significant improvement over the present direct-drive system.

2. The higher frequencies contained in the new EMP threat (approx. 300 MHz - 1 GHz) appear to the aircraft to be optical in nature; cavity resonance and aperture coupling will dominate; and the transient nature of the signal will make Q-resonances difficult. Additionally, the optical nature of this threat will make bounding the coupling difficult using a few measurements at different aspect angles.

3. The power spectral density of the new threat drops off significantly at the higher frequency and is many dB down at 1 GHz. This may make it possible to envelope (bound) the stress without having an over-rigorous waveform.

4. Because the stable waveform resonances are due to the lower frequency components, the high level pulser may only require a modest improvement in risetime 3-4 ns to allow accurate bounding of the system's structural resonance data.

Additionally, to bound uncertainties the stress to strength margin will be 20 dB.

VALIDATION

Free-field EM simulators at Patuxent River include the HPD, VPD and LLCW test facilities. Table 1 provides an overview of the minimum aircraft test orientations to be used at each of the EM simulators and a summary of the approximate operational frequency range of each simulator. Benefits of using an improved fast rise-time pulser will be investigated if resources are available.

Table 1. Aircraft Test Orientations and Facility Frequency Range Capabilities

Facility	Frequency Range	Aircraft Fuselage Orientations (Relative to the E-Field)
Horizontally Polarized Dipole	100 kHz to 100 MHz	1) E-Field Parallel 2) E-Field Perpendicular 3) 45° Rotation*
Vertically Polarized Dipole	1 MHz to 5[illegible] MHz	1) Nose-On 2) Wing-On 3) 45° Rotation*
Horizontally Polarized LLCW	300 kHz to ≥ 1 GHz	1) E-Field Parallel 2) E-Field Perpendicular 3) 45° Rotation*
Vertically Polarized LLCW	300 kHz to ≥ 1 GHz	1) Nose-On 2) Wing-On 3) 45° Rotation*

The "45° Rotation" will only be used during the validation test.

The proposed validation concept will be implemented in two phases. Phase I uses HLP to provide the threat-level E-field magnitudes in the range of 100 kHz to 100 MHz, LLCW to provide low-level E-fields in the range of 300 kHz to 1 GHz, and wideband direct-drive testing at frequencies up to 1 GHz. LLCW test data will be used initially to determine the upper bound for high frequency (HF) coupling to aircraft and will become an integral part of the stress envelopes developed for use during direct-drive.

The aircraft test orientations at the horizontally polarized EM simulators will include (as a minimum) E-field parallel, E-field perpendicular, and a 45° rotation of the aircraft fuselage. Test orientations at the vertically polarized EM simulators will include (as a minimum), Nose-On, Wing-On, and a 45° rotation of the aircraft fuselage. The 45° rotation orientations will be used to investigate aperture coupling at the higher frequencies available during LLCW tests and to support investigation of correlation between LLCW and HLP test data, as well as providing additional data to assist in bounding coupling responses. Testing will continue through conduct of one, or more, validation tests until the concept is validated or a reasonable level of fidelity is achieved.

To further assist the bounding process at the higher frequencies, analytical/numerical analysis will be performed to develop worst case coupling scenarios. Additionally, empirical data gained from other systems using TE/TM and mode-stir chambers will be used to gain further insight. EMEGS will be used for shipboard environment coupling studies

Figure 1 illustrates the stress envelope construction concept. This method provides an envelope that combines all test data to bound system stress. Stress response waveforms are acquired using different simulators (HPD, VPD, LLCW) and aircraft test orientations (parallel, perpendicular, and 45 degrees to simulator). The dominant poles (frequency and magnitude) and the time domain norm attributes of the individual stress responses are integrated into the worst-case stress envelope. Benefits of this approach include efficient use of all test data, development of a more conservative direct-drive waveform and a more accurate bound for the response profile.

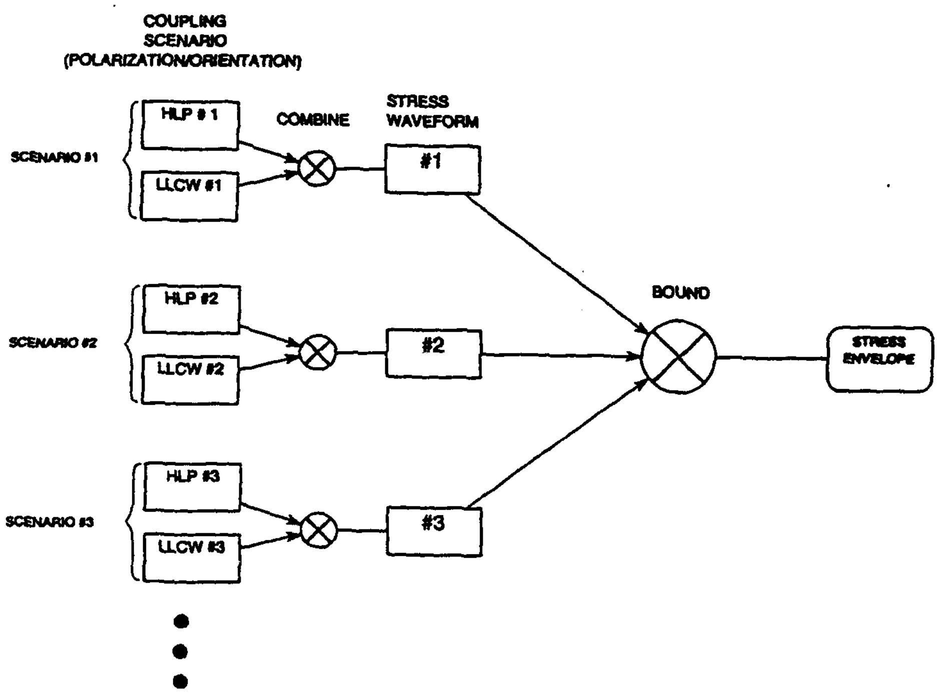

Figure 1. Construction of Stress Envelopes

Wideband direct-drive tests will be conducted using bounded waveforms to characterize system strength for selected test points. High frequency direct-drive (strength) data have not been acquired in the past. Using improved direct-drive capabilities and stress envelopes as the drive waveform, direct-drive tests will be conducted with a goal of demonstrating at least a 20 dB margin of survivability. Wideband direct-drive capabilities, needed to characterize system strength to the HF threat, will be provided using a mix of direct-drive systems. Test results will be characterized to evaluate the differences between the present direct-drive system, wideband direct-drive, and charged line pulser systems and to determine the high frequency influences on aircraft systems.

BENEFITS

This program may provide a high-fidelity, low-cost, low-risk alternative to the full-threat environment simulation approach. Based on stress and strength characterization, system survivability margins to HF threats will be determined.

TECHNICAL ISSUES

The following technical issues must be addressed and resolved:

1. Minimum improvements to present test capabilities and methodologies, needed to assess and validate aircraft survivability in a cost-effective manner, must be defined. Capabilities to be addressed include simulation facilities (HLP and LLCW simulators, and direct-drive systems), instrumentation and data acquisition systems (current probes and sensors, fiber optic data links, and transient digitizers), and improvements to data processing and analysis techniques.

2. The actual change presented by the HF threats, relative to the previous threat waveforms (such as the Bell Laboratories generalized high-altitude EMP waveform), should be quantified in terms of stress and strength. The effect of the expanded EM threat on aircraft survivability must be determined. For example, the effects of cavity resonances, aperture coupling effects and E-field angle of incidence relative to the aircraft POEs should be investigated.

3. The proposed technical concept must be validated using existing technology for HLP, LLCW, and enhancements to current wideband direct-drive test techniques to evaluate weapons systems survivability to HF threats. Following this initial validation phase, after the higher frequencies are bounded, LLCW testing will be eliminated and the test methodology will consist of HLP and wideband direct-drive. The concept, when final validation is complete, may prove to be adequate to meet only certain types of systems.

SUMMARY AND CONCLUSIONS

Requirements established by the latest EMP threat present a challenge to the EMP test and evaluation community. The Navy has taken the initiative to provide a realistic test capability for assessing aircraft survivability to the HF threats. The technical approach presented in this paper is a low-cost, high-fidelity, low-risk alternative to assessment by simulated, full-threat illumination. Development of capabilities for full-threat evaluations of aircraft to the HF threat requires implementation of the approach defined in this paper, development of simulators and test techniques capable of meeting the specifications, or significant enhancements to existing facilities.